

# DuPont Fuel Cells

## DuPont™ Nafion® PFSA Membranes

### N 115, N 117, N 1110

#### Description

DuPont™ Nafion® PFSA membranes are non-reinforced films based on chemically stabilized perfluorosulfonic acid/PTFE copolymer in the acid ( $H^+$ ) form. The physical properties remain the same for the chemically stabilized membranes, which exhibit substantially lower fluoride ion release compared to the non-stabilized polymer – a sign of improved chemical durability. Nafion® PFSA membranes are widely used for Proton Exchange Membrane (PEM) fuel cells and water electrolyzers. The membrane performs as a separator and solid electrolyte in a variety of electrochemical cells that require the membrane to selectively transport cations across the cell junction. The polymer is chemically resistant and durable.

#### Order and Packaging Information

Membrane dimensions are based on dry product conditioned at 23 °C and 50% Relative Humidity before cutting. The membrane's water content will affect its dimensions, and the change may not be symmetrical in the length, width, and thickness directions. In addition, certain conditioning steps performed by the customer also may affect the dimensions. Customers may wish to review their membrane treatment steps and dimensional requirements with a Nafion® technical representative before establishing membrane shipping dimensions.

##### Standard dry product dimensions for individual pieces include:

**Width:** 0.30 m (min.) to 1.22 m (max.)

**Length:** 0.30 m (min.) to 1.22 m (max.)

The membrane delivery package for cut pieces will depend on the size and quantity of the membrane order. Smaller-sized membranes are shipped flat, while longer lengths of individual pieces are shipped on a roll. The membranes are protected with a polyethylene wrap and inner packaging, then placed in shipping containers.

##### Standard dry product dimensions for roll goods include:

**Width:** 12-in (0.305-m) and 24-in (0.610-m) standard roll widths, and roll widths from 0.20-m (min.) up to 1.22-m (max.) on special order. Intermediate widths available in increments of 0.125-in.

**Length:** 50-meter standard roll length

There is a 100 m<sup>2</sup> minimum order requirement for non-standard roll widths and lengths. Membrane pieces or rolls can be cut to custom sizes, and special packaging provided at additional cost and/or delivery time. Please contact Nafion® customer service for details.

EXHIBIT A



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# Properties of Nafion® PFSA Membrane

## A. Thickness and Basis Weight Properties<sup>1</sup>

Membrane Type	Typical Thickness (microns)	Basis Weight (g/m <sup>2</sup> )
N 115	127	250
N 117	183	360
N 1110	254	500

## B. Physical and Other Properties<sup>2</sup>

Property	Typical Value	Test Method
<b>Physical Properties</b>		
Tensile Modulus, MPa (kpsi)		
50% RH, 23 °C	249 (36)	ASTM D 882
water soaked, 23 °C	114 (16)	ASTM D 882
water soaked, 100 °C	64 (9.4)	ASTM D 882
Tensile Strength, maximum, MPa (kpsi)		
50% RH, 23 °C	43 (6.2) in MD, 32 (4.6) in TD	ASTM D 882
water soaked, 23 °C	34 (4.9) in MD, 26 (3.8) in TD	ASTM D 882
water soaked, 100 °C	25 (3.6) in MD, 24 (3.5) in TD	ASTM D 882
Elongation at Break, %		
50% RH, 23 °C	225 in MD, 310 in TD	ASTM D 882
water soaked, 23 °C	200 in MD, 275 in TD	ASTM D 882
water soaked, 100 °C	180 in MD, 240 in TD	ASTM D 882
Tear Resistance - Initial, g/mm		
50% RH, 23 °C	6000 in MD, TD	ASTM D 1004
water soaked, 23 °C	3500 in MD, TD	ASTM D 1004
water soaked, 100 °C	3000 in MD, TD	ASTM D 1004
Tear Resistance <sup>3</sup> - Propagating, g/mm		
50% RH, 23 °C	>100 in MD, >150 in TD	ASTM D 1922
water soaked, 23 °C	92 in MD, 104 in TD	ASTM D 1922
water soaked, 100 °C	74 in MD, 85 in TD	ASTM D 1922
Specific Gravity	1.98	—
<b>Other Properties</b>		
Conductivity, S/cm	0.10 min	see footnote <sup>4</sup>
Available Acid Capacity, meq/g	0.90 min	see footnote <sup>5</sup>
Total Acid Capacity, meq/g	0.95 to 1.01	see footnote <sup>5</sup>

<sup>1</sup> Measurements taken with membrane conditioned to 23 °C, 50% relative humidity (RH).

<sup>2</sup> Physical Properties measured for N 115. Where specified, MD - machine direction, TD - transverse direction. Conditioning state of membrane given. Measurements taken at 23 °C, 50% RH.

<sup>3</sup> Tear resistance (g/mm) of dry membrane increases with thickness. Values given measured using 50 micron membrane.

<sup>4</sup> Conductivity measurement as described by Zawodzinski, et.al, *J. Phys. Chem.*, 95 (15), 6040 (1991). Membrane conditioned in 100 °C water for 1 hour. Measurement cell submersed in 25 °C D.I. water during experiment. Membrane impedance (real) taken at zero imaginary impedance.

<sup>5</sup> A base titration procedure measures the equivalents of sulfonic acid in the polymer, and uses the measurement to calculate the acid capacity or equivalent weight of the membrane.

## Properties of Nafion® PFSA Membrane

### C. Hydrolytic Properties<sup>2</sup>

Property	Typical Value	Test Method
<b>Hydrolytic Properties</b>		
Water content, % water <sup>6</sup>	5	ASTM D 570
Water uptake, % water <sup>7</sup>	38	ASTM D 570
Thickness change, % increase		
from 50% RH, 23 °C to water soaked, 23 °C	10	ASTM D 756
from 50% RH, 23 °C to water soaked, 100 °C	14	ASTM D 756
Linear expansion, % increase <sup>8</sup>		
from 50% RH, 23 °C to water soaked, 23 °C	10	ASTM D 756
from 50% RH, 23 °C to water soaked, 100 °C	15	ASTM D 756

### Recommended Roll Storage Conditions

Unopened roll packages of Nafion® PFSA membrane should be stored in the original shipping box, out of direct sunlight, and in a climate-controlled environment, maintained at 10 to 30°C, and 30 to 70% relative humidity. Before opening the package, pre-condition the membrane roll to the processing area temperature for 24 hours.

Once opened and exposed to the environment, the membrane will equilibrate to the ambient relative humidity, and change in dimensions accordingly. Membrane order dimensions are specified and measured at 23°C and 50% Relative Humidity.

### Handling Practices

Ventilation should be provided for safe handling and processing of Nafion® PFSA membrane. The amount of local exhaust necessary for processing Nafion® PFSA membrane at elevated temperatures will depend on the combined factors of membrane quantity, temperature, and exposure time.

### Scrap Disposal

Preferred disposal options are (1) recycling and (2) landfill. Incinerate only if incinerator is capable of scrubbing-out hydrogen fluoride and other acidic combustion products. Treatment, storage, transportation, and disposal must be in accordance with applicable federal, state/provincial and local regulations.

### Safe Handling and Use of Nafion® PFSA Membranes

The following information should be reviewed before handling and processing Nafion® PFSA Membranes:

- DuPont Material Safety Data Sheet for Nafion® PFSA Membranes N 115, N 117 and N 1110
- "Safe Handling and Use of Perfluorosulfonic Acid Products" bulletin (DFC301.0209).
- "Guide to Safe Handling of Fluoropolymer Resins", Fourth Edition, November 2005, Published by the Fluoropolymers Division of the Society of the Plastics Industry, Inc.

<sup>6</sup> Water content of membrane conditioned to 23 °C, 50% relative humidity (RH), compared to dry weight basis.

<sup>7</sup> Water uptake from dry membrane to water soaked at 100 °C for 1 hour (dry weight basis).

<sup>8</sup> Typical MD and TD values. MD expansion is slightly less than TD.

**For information about product offerings from DuPont Fuel Cells, contact:**

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**Caution:** Do not use in medical applications involving permanent implantation in the human body. For other medical applications, see "DuPont Medical Caution Statement", H-50102.



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